Journal of Plantation Crops 16 (Supplement): 61-67

LIGHT PENETRATION PATTERNS THROUGH ARECANUT CANOPY AND LEAF PHYSIOLOGICAL CHARACTERISTICS OF INTERCROPS*

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ABSTRACT

The physiological performance of intercrops of arecanut was studied in relation to transmitted photosynthetically active radiation (PAR). Approximately 27% PAR passed through arecanut canopy. The leaves of shade-grown crop species were thinner having higher chlorophylls on unit fresh weight or leaf area basis. The crops, viz., banana, clove, cocoa, coffee and pepper were unaffected with respect to nitrate reduction (NR) activity showing their shade tolerance. The NR activity of pineapple leaf was less in shade. The distribution pattern of NR activity in roots and leaves showed that most of the crops except pepper and pineapple reduced NO_3^- in leaves substantially. Further there were no direct relationships of endogenous NO_3^- content to its reduction by NR. The reflectance characteristics of leaf surfaces in visible radiation range was also determined.

INTRODUCTION

The photosynthetically active radiation (PAR) which passes through canopy of trees is characterised by large temporal, spatial variability (Ross, 1960) and spectral qualities (Anderson, 1982). Tall palms of arecanut and coconut allow light penetration through their fixed canopies to an extent of around 30% (Nair and Balakrishnan, 1976). In such understorey environments different annual and perennial intercrops have been cultivated. However, there are no detailed studies on seasonal PAR profiles in arecanut plantation and physiological performance of intercrops. This paper deals with such a study on arecanut based high density multispecies cropping system.

MATERIALS AND METHODS

Six crop species viz., banana, clove, cocoa, coffee, pepper and pineapple were cultivated under 20-year-old arecanut palms with a spacing of 2.7 × 2.7m. The intercrops were planted as follows: banana planted at 5.4 × 5.4m, between arecanut and the inter space was planted with clove or cocoa in alternate rows. Pepper (var. Panniyur) vines were trained on every arecanut palm. Two pineapples were planted between two arecanut palms within a row. A single row of coffee at a distance of 1.35 m was planted after every 3 rows of arecanut. The general lay out of planting is shown in Fig. 1. The intercrops and monocrops received identical management practices.

*CPCRI Contribution No. 525.

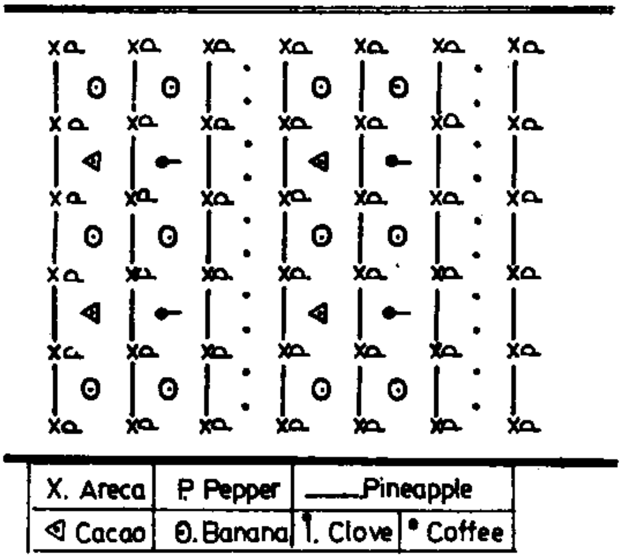

Fig. 1. Layout plan of arecanut based multi species cropping model (Vittal).

Leaves were sampled at 10.00 h for specific leaf weight (SLW), chlorophyll and nitrate reductase (NR) activity determinations. Leaf dry weights/leaf area was determined for specific leaf weight (SLW). Chlorophylls were extracted in 85% acetone (V/v) and estimated spectrophotometrically (AOAC, 1975). For NR activity, the leaves were washed with distilled water, dried with filter paper and cut into *ca* 5 mm discs. The *in vivo* NR assay procedures using 0.2g tissue were employed as described earlier (Jaworski, 1971). The reaction mixture contained 20 mM potassium phosphate buffer pH 7.5 and 100 mM potassium nitrate in a final volume of 5 ml and vaccum infiltrated for 3 min and incubated at 30°C in dark. NO_2^- liberated was estimated using sulphanilamide and N-1-naphthylethylene diamine diHCl. The colour developed was read after 15 min in a Hitachi Model 200-20 double beam spectrophotometer at 540 nm. Tissue NO_3^- was extracted and estimated with chromotropic acid reagent (Sims and Jackson, 1971). Solar radiation was measured using LI-COR quantum radiometer.

RESULTS AND DISCUSSION

The PAR profile during the year showed that on an average 29.8% and 4.6% of full radiation was transmitted through arecanut and banana canopies respectively (Fig. 2). The understorey is interspersed with sunfleck areas and fully shaded areas which changed with the angle of sun and the above mean value was taken from values at noon time. The rainy season had only diffuse light through clouds and the PAR intensity was very low. The interception efficiency of arecanut canopy (i.e.

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was calculated to be about 0.73. The banana canopy which occupied the next understorey allowed very little PAR to pass through.

Adaptation to shade varies among crop species. This involves modifications in leaf anatomy and morphology and how the available light is intercepted and utilised for photosynthesis. The leaves of all the crops studied here were thinner under shade as compared to sole crops. Season and light (shade or open) influenced SLW significantly in all species studied. Leaves of open crops showed significantly lower chlorophyll content than leaves in shaded crops (Table I). It is generally reported that leaves of plants grown in shade have lower SLW than sun leaves (Boardman, 1977; Fails *et al.*, 1982). The SLW is an important indicator of photosynthesis as it has been positively correlated with net photosynthesis (Barden, 1977). Although it was reported that shade plants contained a higher

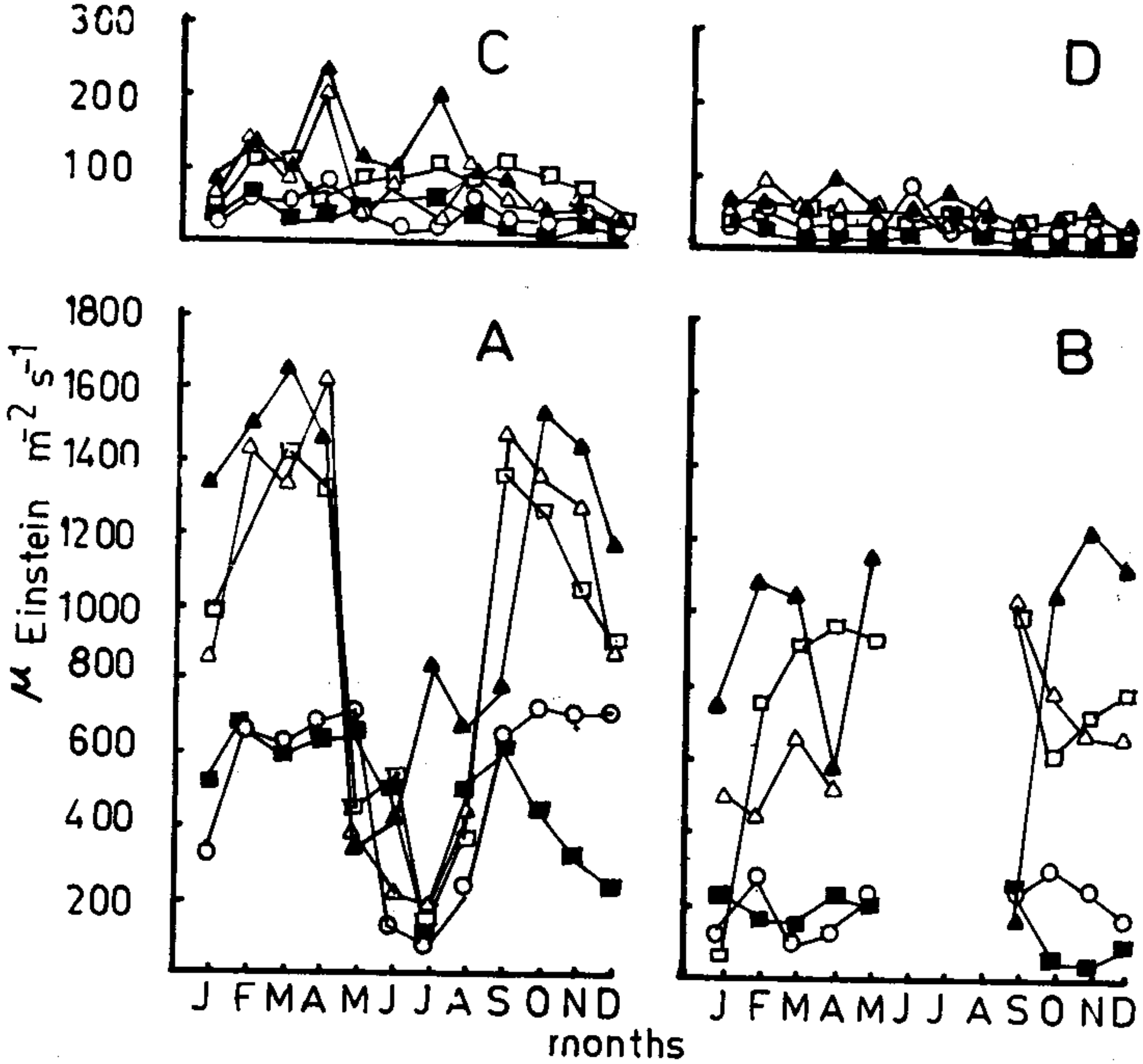

Fig. 2. Seasonal PAR profile under arecanut canopy, sunfleck area (B), arecanut canopy shade area (C), banana canopy shade area (D), and full radiation (A): At 8.00 h (O), 10.00 h (△), 12.00 h (▲), 14.30 h (□) and 16.30 h (■); Mean transmission of PAR through arecanut and banana canopies were 29.8% and 4.6% respectively at 12.00 h.

proportion of Chl b relative to Chl a (Boardman, 1977), no such ratio could be observed in all the crops studied by us. The plants grown under limiting light conditions always recorded higher chlorophyll contents expressed on weight/area basis than did sun plants (Bjorkman, 1968; Boardman, 1977). This clearly demonstrates that shade leaves invest more energy in the production of more light-harvesting systems than do sun plants. The NR activity was determined in leaves of intercrops and compared with sole crops except in case of clove which could not be grown in the open (Table I). In cocoa there was no appreciable change in open and shade conditions. However, since PAR was

Table I. *Means for leaf characteristics of intercrops.*

Crop	Seasons: Jan	Apr	Jun	Sep	Dec	C.D. for comparing seasons	Shade	Open	C.D. for comparing shade and open
				Specific leaf weight (mg cm^{-2})					
Banana	6.29	7.08	9.28	8.67	–	1.03	6.93	8.69	0.73
Cocoa	7.15	5.96	5.81	5.32	5.36	0.73	5.49	6.34	0.46
Coffee	6.24	6.67	5.6	5.39	5.39	0.66	5.09	6.63	0.42
Pineapple	17.50	18.52	18.23	16.36	16.54	1.56	15.17	19.70	0.99
Clove* (Shade)	6.64	–	6.99	8.36	–				
Pepper* (Border)	–	5.78	–	7.59	–				
Pepper* (Interior)	5.52	4.43	–	6.56	–				
				Chlorophyll content (mg g^{-1} fresh weight)					
Banana	1.47	1.11	1.33	1.41	–	0.24	1.55	1.11	0.17
Cocoa	1.14	1.49	1.23	1.24	1.67	0.25	1.58	1.13	0.16
Coffee	1.70	1.48	1.05	1.30	1.89	0.24	1.94	1.02	0.15
Pineapple	0.19	0.21	0.16	0.30	0.24	0.05	0.29	0.15	0.03
Clove* (Shade)	1.76	–	1.26	1.24	–				
Pepper* (Border)	–	1.51	–	1.18	–				
Pepper* (Interior)	2.05	1.31	–	1.27	–				
				NR activity (n moles g^{-1} fresh wt. h^{-1})					
Banana	369	221	131	128	–	72	206	219	NS
Cocoa	431	273	241	258	212	88	290	276	NS
Coffee	360	388	147	225	277	90	414	145	57
Pineapple	45	85	32	57	26	20	39	59	12
Clove* (Shade)	99	–	28	38	–				
Pepper* (Border)	–	78	–	90	–				
Pepper* (Interior)	231	115	–	84	–				

CD (P = 0.05)
*Statistical analysis not performed

relatively high during April the activity of enzyme decreased. Cocoa is a shade loving crop and excessive PAR can cause inhibition of enzyme and photo-bleaching (Balasimha, 1982). The NR activity in coffee adversely inhibited in sole crop. In pepper, there was no significant variation between the border and interior plants. Pineapple and clove showed very low NR activity as compared to other crops and in the former it was more in sole crop. In banana, although the activity was unaffected under shade in initial period of growth, it decreased towards later part of growth in both varieties.

Seasonal trends in NR activity has been reported in several field grown crops

Table II. *Distribution of nitrate reductase activity and nitrate content in leaves and roots of intercrop species.*

	Without induction		Induction with nitrate*	
	Leaf	Root	Leaf	Root
	Nitrate reductase (n moles g^{-1} fresh wt. h^{-1})			
Banana	50.5 ± 17.2	23.7 ± 2.2		
Clove	58.6 ± 1.8	16.7 ± 4.7	108.3 ± 24.8	27.0 ± 11.0
Cocoa	177.0 ± 6.9	33.5 ± 14.9	484.0 ± 175.0	69.0 ± 15.0
Coffee	381.0 ± 27.1	145.3 ± 13.6	783.7 ± 278.8	99.0 ± 34.0
Pepper	44.3 ± 7.4	122.3 ± 25.4	503. 7 ± 126.1	256.0 ± 39.8
Pineapple	29.2 ± 3.9	61.6 ± 16.7		-
	Nitrate content (μg/g dry weight)			
Banana	865 ± 315	610 ±110	-	
Clove	120 ± 20	148 ± 42	513 ± 220	365 ± 185
Cocoa	470 ± 60	687 ± 74	430 ± 122	843 ± 342
Coffee	643 ± 338	1740 ± 615	3430 ± 250	5573 ± 1140
Pepper	293 ± 143	186 ± 112	2440 ± 876	621 ± 112
Pineapple	1431 ± 240	453 ± 253	-	-

*Seedlings were treated with 20 mM KNO_3 for 3 days and sampled

(Harper *et al.*, 1972; Teare *et al.*, 1974) and in cocoa (Balasimha, 1982). The NR activity was generally higher when the PAR received by leaves was more. It is interesting to note that in banana the capacity to reduce NO_3^- declined gradually with maturity. This was more pronounced in shade plants and showed shade tolerance of banana varied depending on the plant's ontogenetic stage. Canopy variations of NR activity in cocoa plants have been reported (Balasimha, 1982). Canopy variations in pepper and banana were determined. The activity was always reported to be less in shaded leaves (Balasimha, 1982; Harper *et al.*, 1972; Teare *et al.*, 1974) in crops studied. The same trend was noticed in pepper. The NR activity (n moles g^{-1} h^{-1}) was 114.5 and 77.8 in upper and lower canopy levels of border plants respectively. However, in banana the middle and lower leaf positions recorded higher NR activity; 1st-740, 2nd-440, 3rd- 430, 5th-460, 7th-680 nmoles g^{-1} h^{-1} respectively.

In order to determine whether the NO_3^- assimilation occurs in either of two sites among these crop species, NR was assayed in leaves and roots (Table II). In banana, clove, cocoa and coffee the major reduction occurred in leaves. This became more evident when the plants were substrate induced with NO_3^- solution. In pepper and pineapple however, roots took a major part in reducing NO_3^-. Under non-inductive conditions pineapple accumulated maximum NO_3^- but did not show any corresponding increases in NR activity. No direct relationship could be ascribed to NR activity and NO_3^- content in either leaf or root (Table II). But external supply of NO_3^- enhanced NR activity in leaves only remarkably except in pepper where it was enhanced in roots also substantially. Comparisons of rates of NO_3^- reduction

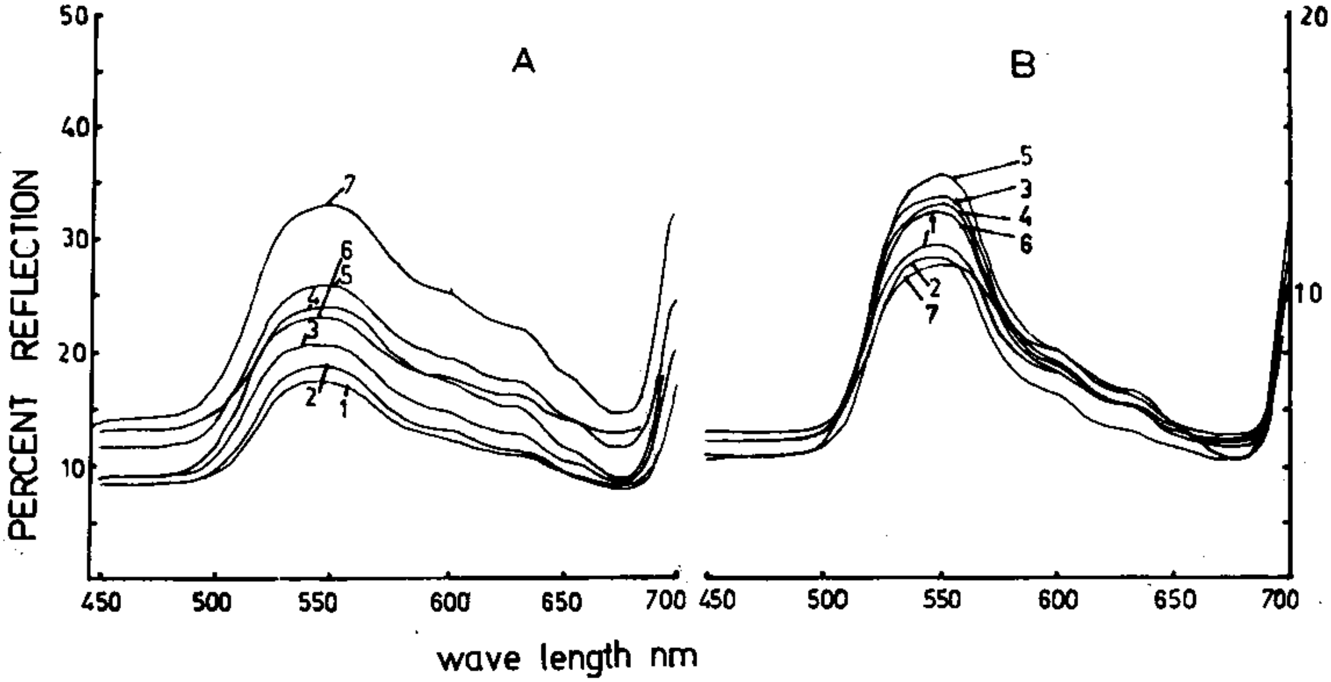

Fig. 3. Leaf reflection of leaf back (A) and front (B) surfaces; Pineapple reflection alone in B has full scale of 50% R; Numbers on curves represent arecanut (1) banana (2), cocoa (3), clove (4), coffee (5), pepper (6) and pineapple (7).

among species have shown that some species reduced considerably more in roots than in leaves (Olday *et al.*, 1976; Radin, 1978). This difference in distribution could be correlated with amounts of NO_3^- accumulated by plant parts. But in the crops studied by us no such relationship could be found. It can be argued that nitrate reduction cannot be totally influenced by the presence of NO_3^- and the potential NR activity in plants is considerably higher than that actually required. This is clearly discernible ad NR activity was considerably lower under natural environment but increased under inductive conditions.

Reflectance of leaf surfaces of these crops was measured as a function of wavelength in visible range with a Hitachi double beam model 200-20 Spectrophotometer fitted with an integrating sphere (Fig. 3). In the wavelength band 400-700 nm major portion of radiation is absorbed and the reflection curve showed a peak at 550 nm. The leaves of pineapple showed highest reflection which may be due to the thick leaf structure. The valuable detailed study of the directional and spectral reflectance properties of various plant genera have been studied by Woolley (1971) who also showed that thick leaves reflected more in 400-700 nm wave band. Leaves however, reflect as much as 96% of light in infra-red range i.e. 800-1100 nm (Woolley, 1971). the significance of such data have to be viewed in as much as intercropping under taller trees are considered. Since, the shade cast by trees and transmitted light will be richer in non-PAR it is essential that the intercrop species should be able to adapt to such an environment.

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